Performance Investigation on Lossy Still Image wavelet Compression using different wavelet filter functions

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Abstract— The aim of this paper is to observe a set of wavelet for achievement in a still image compression system and to accentuate the advantage of this transform involving to today's methods. This paper discusses significant features of wavelet transform in compression of still images, including the scope to which the quality of image is degraded by the method of wavelet compression and decompression. Image quality is measured objectively, using Peak Signal-to-Noise Ratio (PSNR), and subjectively, using apparent image quality. The effects of different wavelet functions, image contents and Compression Rate (CR) are assessed. A comparison among the different wavelets based compression system is given in this paper. Our results provide a good suggestion for application developers to choose a good wavelet compression system for their application.

Keywords- Image Compression; Wavelet Compression; Peak Signal Noise Ratio; Compression Rate; Wavelet Filters.

I. INTRODUCTION

In recent year's do research in computer graphics has professed significant activity focused on the use of wavelets, as in many other disciplines**.** [1, 4]Wavelets are mathematical tool for methodical decomposing function as they allow a role to be described in terms of a coarse overall shape, plus details from wide to thin range irrespective of whether the function of interest is an image wavelet, after an well-designed technique for representing the levels of detail existing. Although wavelets have their roots in approximation theory and signal processing, they have currently been applied to many problems in computer graphics. These graphics application include image editing, image compression and image classification etc. as well. In the present era image processing has emerged considerably and is extensive in research area in computer graphics, as image processing is technique for analysis and manipulation of image and also improves a quality of an image. Image processing in computer is used to change the nature of image. The introduction of wavelets to signal and image processing has provided a very flexible tool for engineering so as to create novel techniques for solving various engineering difficulties. Nowadays, in internet and multimedia technology much information is being accessed having a large amount of data and it requires more storage space in disk. In many fields, digitized image are replacing usual analog image as photograph and medical image or x-rays. The size of data necessary to give detailed images greatly show transmission and makes storage greatly expensive. The information curbed in the image must therefore be compressed by removal of merely visible elements, which are then encoded. The unprocessed image heavily consumes very important resources of the system; uncompressed image requires large memory to store the image and large bandwidth to transmit the image data, are incapable to handle a recent technology, also cost-effectively it has very hard processing. So, the solution to this problem is to compress the information and storage space and transmission is reduction of redundancy and irrelevancy. Redundancy reduction aims at removing repetition form of image and irrelevancy reduction omits parts of the signal that will not be noticed by human visual system.

A variety of new and classy wavelet-based image coding schemes and other lossless schemes have been developed. This includes Embedded Zero tree Wavelet (EZW) [11], Set Partitioning in Hierarchical Trees (SPIHT) [5, 8, 11, 16], Compression with Reversible Embedded Wavelets (CREW) [2], Embedded Predictive Wavelet Image Coder (EPWIC) [3], Embedded Block Coding with Optimal Truncation (EBCOT) [8, 12], Second Generation Image Coding[2], JPEG [6], JPEG-2000 [6] and Lossless Image Compression using Integer Lifting [4]. Similarly the bandwidth requirement for transmitting the image data is very large and for high performance applications like medical imaging and satellite imaging; a high quality image is very important when reproduction which leads to classify the data for decision making. In order to meet the requirements, effective image compression algorithms are needed. In lossless compression schemes, reconstructed image is numerically identical to original, offers very low compression ratio, where as lossy schemes do not bound to perfect reconstruction and provide satisfactory quality at a fraction of the original bit rate. In this proposed algorithm, the lossy image compression algorithm using different wavelets has been taken for analysis, which yields better bit rates and PSNR.

The paper is organized as follows; Section-2 presents the basic lossy wavelet image compression algorithm described in [6, 7]. Section-3 presents the proposed algorithm with different wavelet filter functions, Section-4 contains discussion about the results and Section-5 presents the conclusions.

II. BASIC LOSSY WAVELET IMAGE COMPRESSION

The process of image compression based on wavelet transform coding [7, 9] is shown in Figure.1. The purpose of the wavelet transform is to de-correlate the image, the process is loss-less and reversible when calculating errors are ignored. A series of wavelet coefficients is formed in the transform domain after the image de-correlation, which is quantized to integers to a code bit stream to be transmitted down. The quantization is neither lossless nor reversible, and is mainly responsible for image distortion. Fig.1 shows the process of decoding and recovering image, it is the reverse of Fig.2. It is similar to JPEG 2000 Compression Standard.

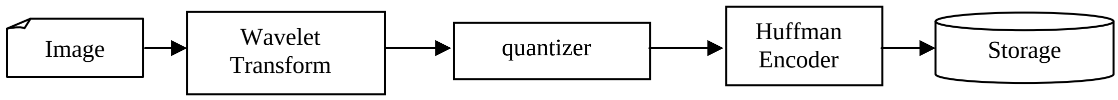


Fig.1 Sketch of image wavelet transform and coding.

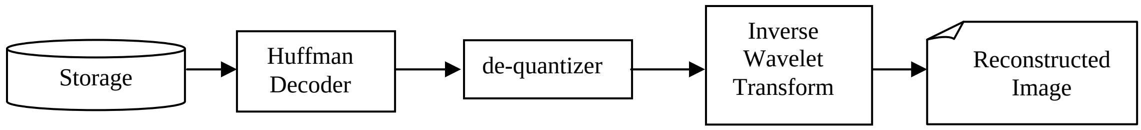


Fig.2 Sketch of image recovery and decoding.

A. Wavelet Encoder

Step-1: Read the image.

Step-2: Convert if the image is in the mode of RGB to Gray.

Step-3: Apply Wavelet Transform on the image with specific scaling and quantization.

Step-4: Quantize the image.

Step-5: Encode the result of step-4 using Huffman Encoding Scheme and store the Encoded / Compressed image.

Step-6: Find the metrics of Compression Rate (C_R).

B. Wavelet Decoder

Step-1: Read the Compressed / Encoded image.

Step-2: Decode the image using Huffman Decoding Scheme.

Step-3: De-quantize the image.

Step-4: Apply Inverse Wavelet Transform on the result of step-3. Show the original and reconstructed Image.

Step-5: Find the metrics of Peak Signal to Noise Ratio (PSNR).

C. Performance Measures [6, 7, 9]

Appropriate performance metrics are required to evaluate the performance of a specific image compression scheme. An image compression algorithm can be evaluated in many different ways according to different requirements. Major compression metrics include compression ratio, compression speed, computing complexity, memory and storage complexity, objective and subjective quality of the reconstructed image, etc.

The most common metric of performance measure [6, 7, 9] of an image compression scheme is the compression ratio, which is defined by the equation (1),

$$Compression\ ratio\ (cr) = \frac{Original\ \ image\ \ size\ \ in\ \ bits}{Compressed\ \ image\ \ size\ \ in\ \ bits} \tag{1}$$

i.e., the number of bits needed to represent the original image data divided by the number of bits needed to represent the compressed image data. The original image size used in this research does not include any image format overhead or byte alignment overhead. For an image of size $M \times N$ and bit depth **b**, the original image **(y)** size is simply calculated by the following equation (2),

$$Original\ \ image\ \ size\ \ in\ bits\ = M \times N \times b \tag{2}$$

On the contrary, the compressed image size counts all head and tail overhead needed to reconstruct the original image. For example, if an image of size 512 x 512 with 8 bits per pixel is compressed to 8192 bytes, the compression ratio will be 32 : 1 or 32.

Another way to evaluate image compression performance is to use compression rate in the unit of bits per sample or bits per pixel (bpp), which is defined as the average number of bits used to represent a single sample (pixel). The compression rate is given by the equation (3),

$$Compression\ rate\ (CR) = \frac{Compressed\ \ image\ size\ in\ bits}{Number\ of\ \ pixels} \tag{3}$$

In the above example, the original rate is 8 bpp and the compression rate is $\frac{8192 \times 8}{512 \times 512} = 0.25\,bpp$. Note that a larger value of compression ratio or a smaller value of compression rate indicates better compression performance of a compression scheme.

Although reconstructed image quality is irrelevant to the lossless image compression schemes, it is very important to find the good quality reconstructed image of lossy compression and near lossless image compression. For lossy and near lossless compression, no one can justify a scheme by considering the compression ratio or compression rate alone, because the scheme which gives higher compression ratio may result in worse reconstruction quality. The most widely used objective quality metric for lossy image compression is the Peak Signal-to-Noise Ratio (PSNR), which is given by the equation (4),

$$PSNR\ = 20\ \ LOG_{10}\left(\frac{A}{e_{rms}}\right) \tag{4}$$

where ‘A’ is the peak (maximum) pixel gray value of the image. For 8-bit gray-scale images, A = 255. ‘e_{rms}’ is Root Mean Square Error, which is calculated by the equation (5),

$$e_{rms}\ = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(y_{ij} - \hat{y}_{ij}\right)^2} \tag{5}$$

where, ‘**y’** is Original Image and ‘ $\hat{y}$ **’** is reconstructed image.

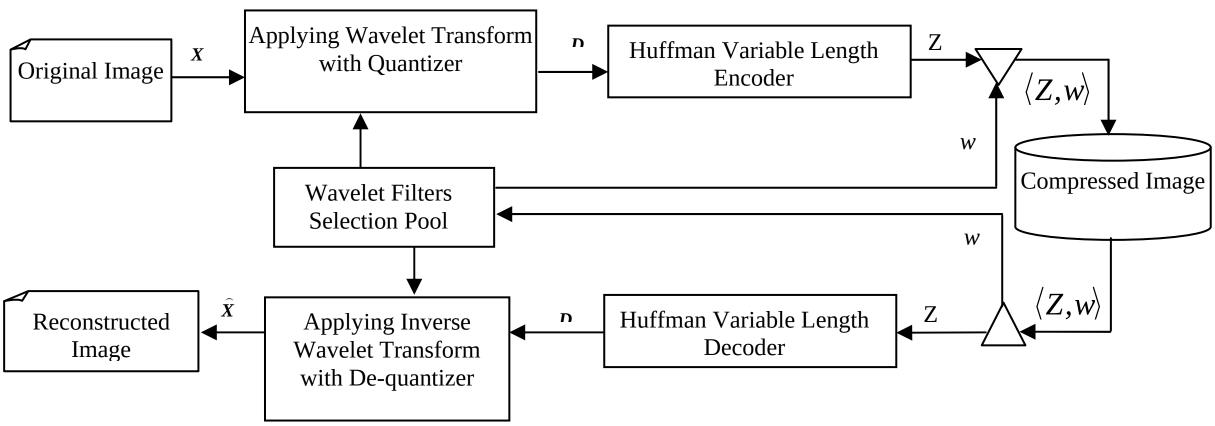


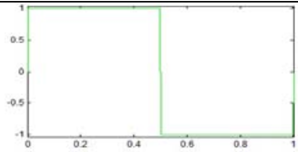
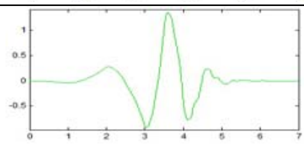
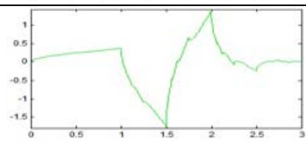
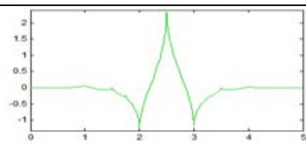
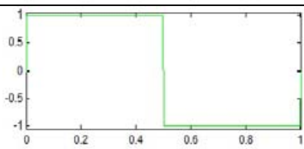
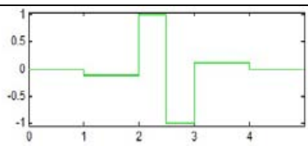
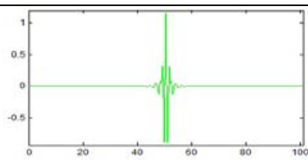
Fig.3 Lossy Wavelet Compression and Decompression Algorithm using wavelet Filters

III. PROPOSED LOSSY WAVELET IMAGE COMPRESSION USING WAVELET FILTERS

The compression and decompression process of this proposed algorithm Lossy Wavelet Image Compression is similar to JPEG 2000 Compression System, as shown in Fig.3. After applying the wavelet transform with quantization on the original image with the selected wavelet filter function from selection pool in proposed Compression System; it is found that there exists a large amount of redundancy in the form of repeated values in the transformed data. This redundancy is reduced by the Huffman coding discussed in [7] and [9] scheme on the transformed data. Huffman encoding scheme produces good compression on the repeated redundant data. The different types of wavelet filter functions are tabulated in Table.1.

The wavelet families are categorized into six families, there are Compactly Supported or Simplest, crude, Infinitely Regular, Orthogonal & compactly supported, Bi-orthogonal & compactly supported and Complex wallet families. In this paper, haar wavelet is a simplest and compactly supported wavelet, Daubechies, Symlets and Coiflets are orthogonal & compactly supported wavelets, Bi-orthogonal and Reverse Bi-orthogonal are Biorthogonal and compactly supported and discrete Meyer is a infinitely regular wavelets.

Table I. Types of Wavelet Filter Functions

S. No.	Name of the Wavelet Filter	Short Name	Wavelet Functions
1	Haar Wavelet	haar	
2	Daubechies-4 Wavelet	db4	
3	Symlets	sym	
4	Coiflets	coif	
5	Biorthogonal-1.1 Wavelet	bior1.1	
6	Reverse Biorthogonal-1.3	rbio1.3	
7	Discrete Meyer Wavelet	dmey	

The costs of the proposed algorithm are restricted similar to JPEG 2000 standard algorithm. The computational cost of the lossy wavelet image compression algorithm is an order of n^2 where 'n' is the number of rows or columns of the image matrix and matrix is a square matrix.

A. Proposed Compression Algorithm

The Compression process of the proposed algorithm has three steps,

Step-1 : Apply the selected Wavelet Transform from the wavelet selection pool (w) on the input Original image pixel $X\ (i,\ j)$ along with the quantizer. The Result is represented as D.

Step-2 : Apply the Huffman encoding on the D. It is represented as (Z)

Step-3 : Calculate the Compression Rate $CR(Z,w)$ for the wavelet filter 'w' using the equation (3) and Increment the *x value by 1 and repeat the Step-2.*

Step-3 : Repeat the Step-1 to Step-3, until all the Wavelet filters were selected.

Finally, the code book $\langle Z(x),w \rangle$ contains the compressed information (*Z*), 4 bit selected wavelet filter code (w*)*.

B. Proposed Decompression Algorithm

Similar to the compression, the decompression process of the proposed algorithm has three steps,

Step-1 : Compressed data, (*Z, w)* is decoded using Huffman decoding technique. The decoded result is represented as D .

Step-2 : Apply the Inverse Wavelet Transform based on the wavelet filter (w) D along with de-quantizer. The result is represented as $\widehat{X}(i, j)$.

Step-3 : Calculate the Peak Signal-to-Noise Ratio with the equation (4) and (5)

Where A is Peak Pixel Gray value, for example 8-bit image A = 255.

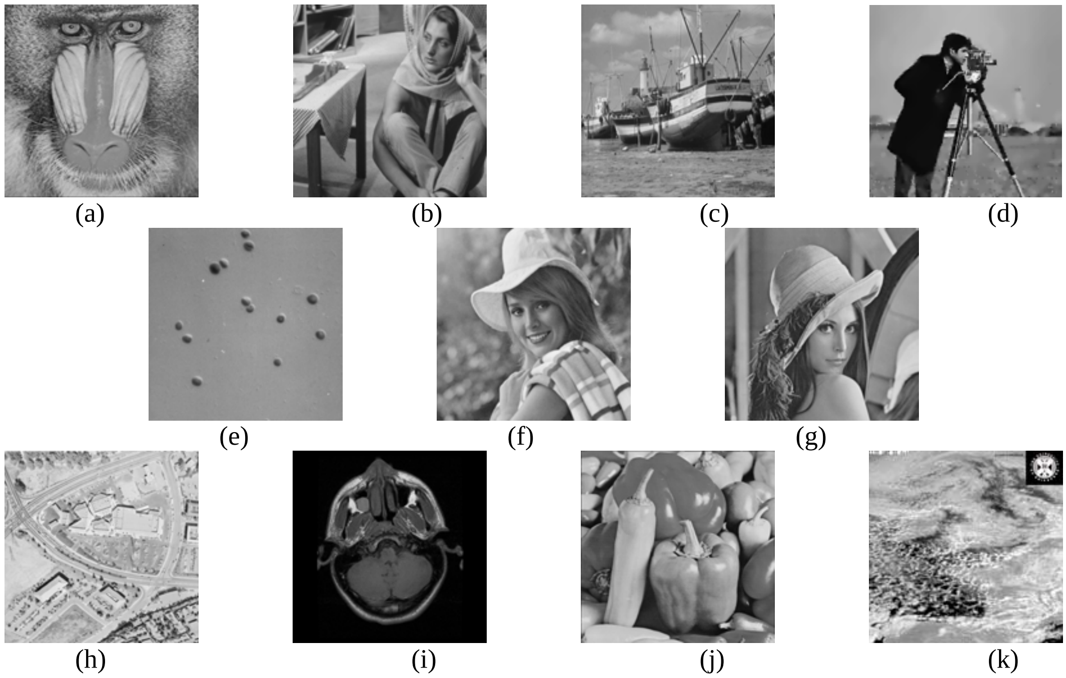


Fig.4 Standard Test Images, (a) Baboon (b) Barbara (c) Boat (d) Cameraman (e) Cells (f) Elaine (g) Lena (h) Landsat-aerial (i) MRI-Brain (j) Pepper (k) UK-Sat

IV. SIMULATION RESULTS AND DISCUSSIONS

Simulation is performed and the programs have been implemented using MATLAB 7.1 and tested with the standard gray scale images Baboon, Barbara, Boat, Cells, Elaine, Finger Print, Landsat-aerial, Lena, MRI-Brain, Pepper and UK_Sat images as mentioned in HTTP link [13, 14, 15]. The 512x512 size digital image Baboon, Barbara, Camera man, Elaine and Lena are the single object standard face image, but Boat and Pepper image has the multiple objects with varying gray levels. ‘Cell’ is a differential interference microscope image (HTTP link [13]) with 512x512 grayscale of algal cells. Landsat-aerial and ‘UK_Sat’ is a 512x512 grayscale satellite images (HTTP link [13]) which was taken over the United Kingdom through Infra-red spectrum. MRI-Brain is an image which is used in medical applications for classification and recognition. These images have been collected as part of a research to analyze with different parameters which is discussed in [6], [7] and [9].

Table II. Compression Rate (CR in bpp) of the proposed algorithm for all test images with types of wavelets

512 x 512 Images	Decomposition Level	Wavelet Names						
		haar	**db4**	**sym**	**coif**	**bior1.1**	**rbio1.3**	**dmey**
Baboon	4	7.5068	**4.459**	6.8341	6.4338	7.507	7.7361	4.9352
	5	5.3042	**2.9434**	4.679	4.3966	5.3044	5.4756	3.3099
Barabara	4	7.908	6.8642	7.2427	7.2161	7.908	8.6273	**6.5242**
	5	5.5477	4.507	4.899	4.8766	5.5478	6.2218	**4.1633**
Boat	4	7.7169	7.1556	7.323	7.3028	7.7171	7.9602	**7.0754**
	5	5.1887	4.5974	4.769	4.7411	5.1888	6.245	**4.5191**
Cameraman	4	3.7775	3.9122	3.5911	**3.5718**	3.778	4.7795	4.4521
	5	2.7777	2.905	2.6523	**2.6251**	2.7782	3.6528	3.1896
Cells	4	5.859	5.7574	5.7917	5.7873	5.8592	**5.7486**	5.764
	5	3.0689	2.9139	2.9413	2.9411	3.069	**2.8993**	2.9279
Elaine	4	7.8728	7.3694	7.4908	7.4689	7.873	7.8504	**7.3579**
	5	5.3464	4.7607	4.8933	4.8667	5.3466	5.9969	**4.7461**
Lena	4	6.3908	5.6725	5.8724	5.3851	6.391	5.6536	**5.6334**
	5	3.9144	3.1682	3.3618	3.3282	3.9145	3.1338	**3.1147**
Landsat-aerial	4	8.4206	**7.8763**	8.0346	8.0072	8.4208	8.8972	7.9467
	5	6.2497	**5.629**	5.8623	5.8286	6.2498	7.6723	5.639
MRI-brain	4	3.5286	2.3281	2.7173	2.7072	3.5287	2.3461	**1.9083**
	5	2.1225	1.3093	2.713	1.5561	2.1227	1.2956	**1.1378**
Pepper	4	7.0057	6.4368	6.5174	6.5089	7.0059	**6.4589**	6.5358
	5	4.353	3.7681	3.8528	3.8432	4.3531	**3.7716**	3.8631
UK-sat	4	2.8965	5.601	7.3863	6.7174	**2.7386**	5.2742	6.9442
	5	2.7299	5.5933	7.3794	6.7101	**2.73**	5.2664	6.9373

Table III. PSNR Value (in dB) of the proposed algorithm for all test images with types of wavelets

512 x 512 Images	Decomposition Level	Wavelet Names						
		haar	db4	sym	coif	bior1.1	rbio1.3	dmey
Baboon	4	44.92	46.19	44.95	45.64	44.92	35.71	**46.22**
	5	42.59	39.85	42.49	42.91	42.59	34.97	**43.68**
Barabara	4	40.2	43.12	39.42	44.78	40.2	35.82	**45.04**
	5	**42.3**	42.12	41.84	42.18	**42.3**	34.99	41.7
Boat	4	44.74	44.86	45.62	45.62	44.74	36.36	**45.74**
	5	**42.32**	41.93	42.22	42.31	**42.32**	35.53	35.12
Cameraman	4	32.92	44.83	44.92	46.31	32.92	36.82	**47.18**
	5	**45.47**	43.62	43.84	44.82	**45.47**	36.4	42.9
Cells	4	38.59	38.61	41.14	41.13	38.59	37.97	**41.16**
	5	**42.81**	42.65	42.62	42.44	**42.81**	42.53	42.57
Elaine	4	40.65	40.72	40.65	46.06	40.65	39.21	**46.57**
	5	**42.68**	42.54	42.53	42.5	**42.68**	36.83	42.45
Lena	4	38.28	36.81	40.68	**46.48**	38.28	37.8	40.77
	5	39.14	42.43	42.46	**42.62**	39.14	38.94	35.20
Landsat-aerial	4	43.5	**44.38**	43.83	43.65	43.5	35.86	44.32
	5	41.72	**42.15**	41.82	41.78	41.72	34.08	41.10
MRI-brain	4	48.27	48.76	48.5	47.31	48.27	49.04	**49.67**
	5	45.36	46.13	**47.63**	45.51	45.36	45.84	46.74
Pepper	4	46.31	43.77	39.88	45.95	46.31	**46.55**	44.8
	5	42.58	42.4	42.13	42.24	42.58	**42.39**	41.7
UK-sat	4	**51.49**	42.75	45.82	46.1	51.22	46.93	46.41
	5	**51.1**	46.43	45.74	45.91	51.1	45.72	46.37

The following standard test images of Figure.4 are collected from the reference (HTTP link [13, 14, 15]), These images are graphics file either Tagged Image File Format (TIFF) or Graphics Interchange Format (GIF) without compression. The histogram of each test image is shown in the Fig.4. The compression rate of the proposed algorithm for different test images with different types of wavelet filters has been tabulated in Table.2, which helps to select the wavelet filters. The proposed method with specific wavelet filters is compared among themselves with different wavelet filters. The objective is to identify the performance of the proposed algorithm. The major parameters Compression Rate (CR) and PSNR values of different standard images with wavelet filters are tabulated in Table II & Table III.

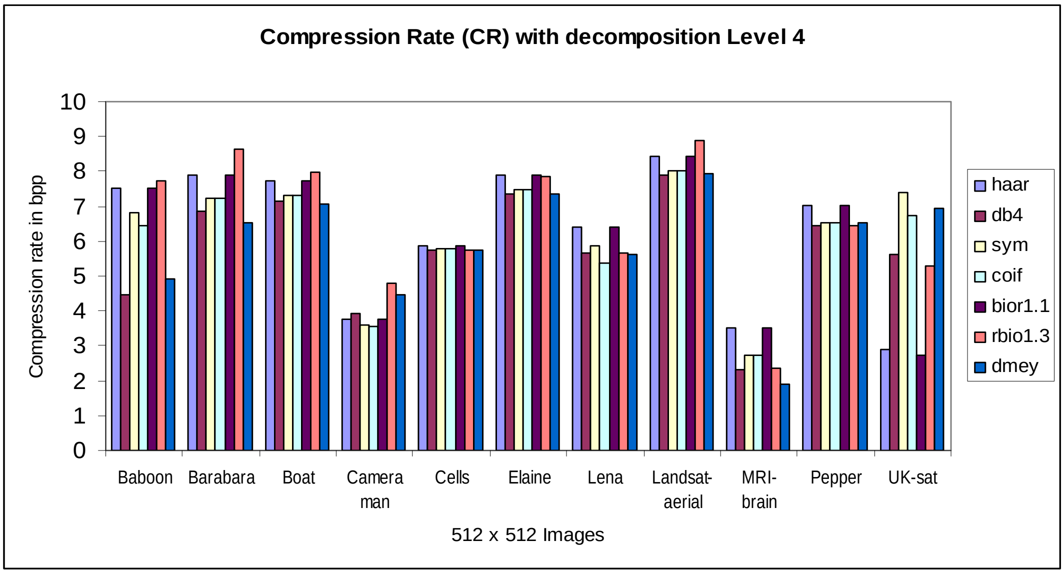


Fig.5 Compression Rate (CR) of test images with various wavelet functions for the decomposition level-4

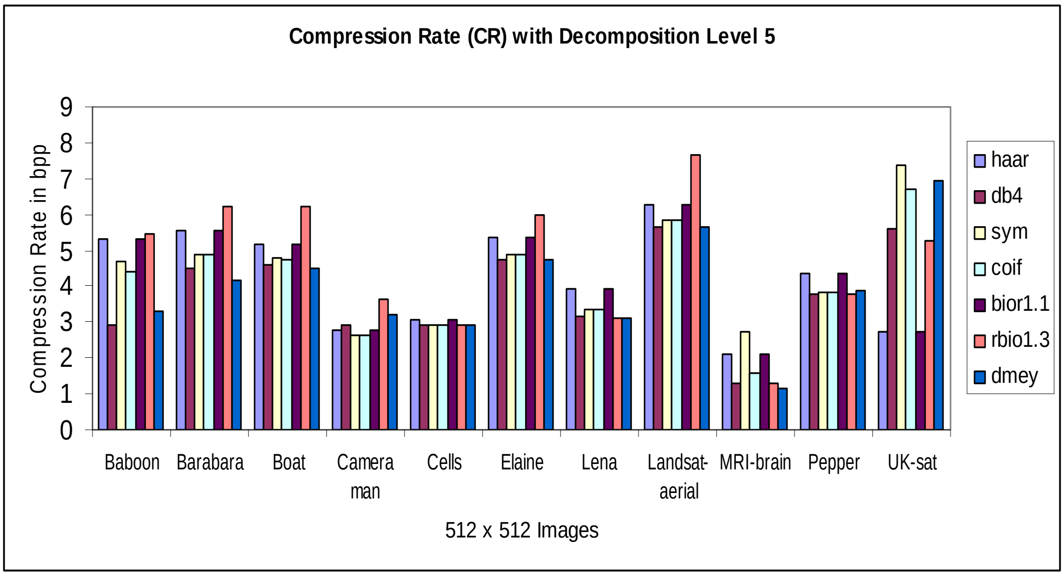


Fig.6 Compression Rate (CR) of test images with various wavelet functions for the decomposition level-5

Based on the observed results as shown in Table II and Fig.5 & Fig.6 for the performance of the proposed algorithm in terms of Compression Rate(CR), it is inferred that the 'dmey' wavelet provides good compression rate (or bit rate in bpp) for the Barbara, Boat, Elaine, Lena and MRI-brain test images, 'db4' achieves good compression rate for the Baboon and Landsat-aerial image, 'rbio1.3' wavelet provides good bit rate for the Cells and Pepper images, 'coif' wavelet achieves good compression for the Cameraman image and 'bio1.1' provides good bit rate for the UK-sat image.

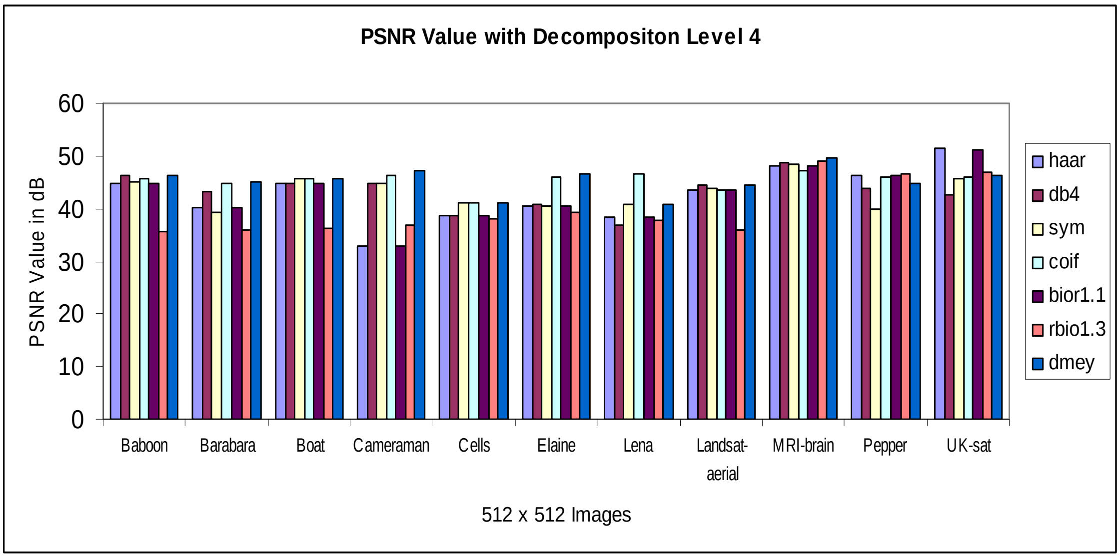


Fig.7 PSNR value of test images with various wavelet functions for the decomposition level-4

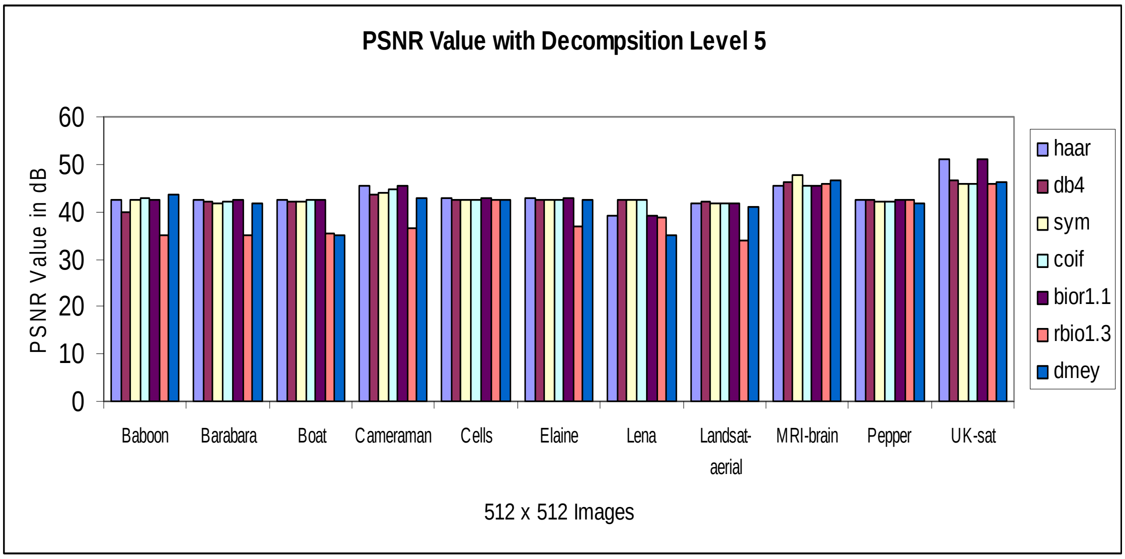


Fig.8 PSNR value of test images with various wavelet functions for the decomposition level-5

Based on the results as shown in Table III and Fig.7 & Fig.8 for the performance of the proposed algorithm in terms of PSNR Value, it is inferred that the 'dmey' wavelet achieves good PSNR value for the Baboon, Barbara, Boat, Cells, Cameraman, Elaine, and MRI-brain test images and produces a high quality reproduced images when decompression, 'coif' wavelet achieves good PSNR value for the Lena test image, 'db4' provides good PSNR value for the Landsat-aerial image, 'rbio1.3' achieve good PSNR value for the Pepper test image and 'haar' wavelet achieves good PSNR value for the UK-sat images.

The performance depends on the image and their selected wavelet Filter. For UK_Sat image, the compression rates is better when applying the 'bior1.1' wavelet and for getting high quality reproduced image, apply 'haar' wavelet as shown in the Figures.5, 6, 7 & 8. The bit rate of all test images using proposed algorithm is differ for various wavelet functions. Also proposed algorithm was developed and mainly aimed for getting good compression and high quality image after reconstruction. The performance of the proposed algorithm is analyzed with different wavelet filter functions for various standard test images as shown in Table II & Table III and Figures.5, 6, 7 &8

V. CONCLUSIONS

In this paper, the lossy wavelet image compression algorithm with different wavelet filter functions has been presented. The specific wavelet filter selection is based on the requirements for the particular image improves the compression rate and decoding process yields good quality reproduced image. Encoding and decoding process of the proposed algorithm is comparatively similar to JPEG 2000 but process was analyzed with different wavelet filter functions. This algorithm is suitable for getting high compression rate as well as getting good quality reproduced image for the applications like storing of still images, medical imaging and satellite imaging where image classifications required.

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